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(54) **TEST SYSTEM AND METHOD FOR TESTING MULTIPLE INPUT MULTIPLE OUTPUT CAPABILITIES**

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H04B 17/391 (2015.01)
H04B 7/0413 (2017.01)

(52) **U.S. Cl.**
CPC ***H04B 17/3912*** (2015.01); ***H04B 7/0413*** (2013.01)

(58) **Field of Classification Search**
CPC H04L 25/03044; H04L 2025/03509; H04L 2025/0349; H04L 27/01; H04L 25/0307; H04B 17/3912; H04B 7/0413; H01Q 1/362; H01Q 21/00
USPC 375/224, 316, 219, 295
See application file for complete search history.

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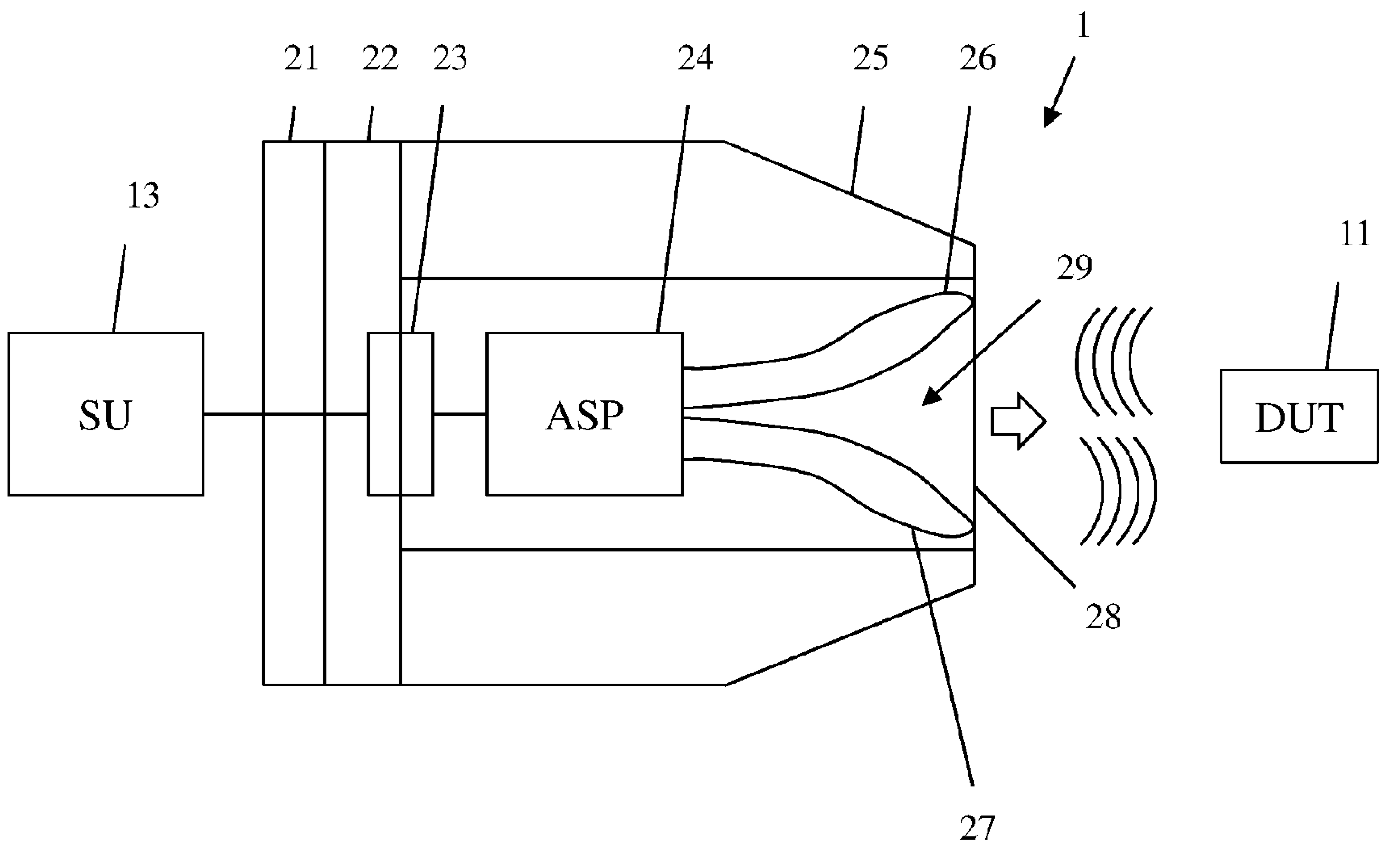
(57) **ABSTRACT**

A test system is used for testing multiple input multiple output capabilities. The system comprises a device under test, a movable antenna and a signal simulation unit. Furthermore, the signal simulation unit simulates at least two multiple input multiple output channels in order to test the multiple input multiple output capabilities of the device under test.

18 Claims, 5 Drawing Sheets



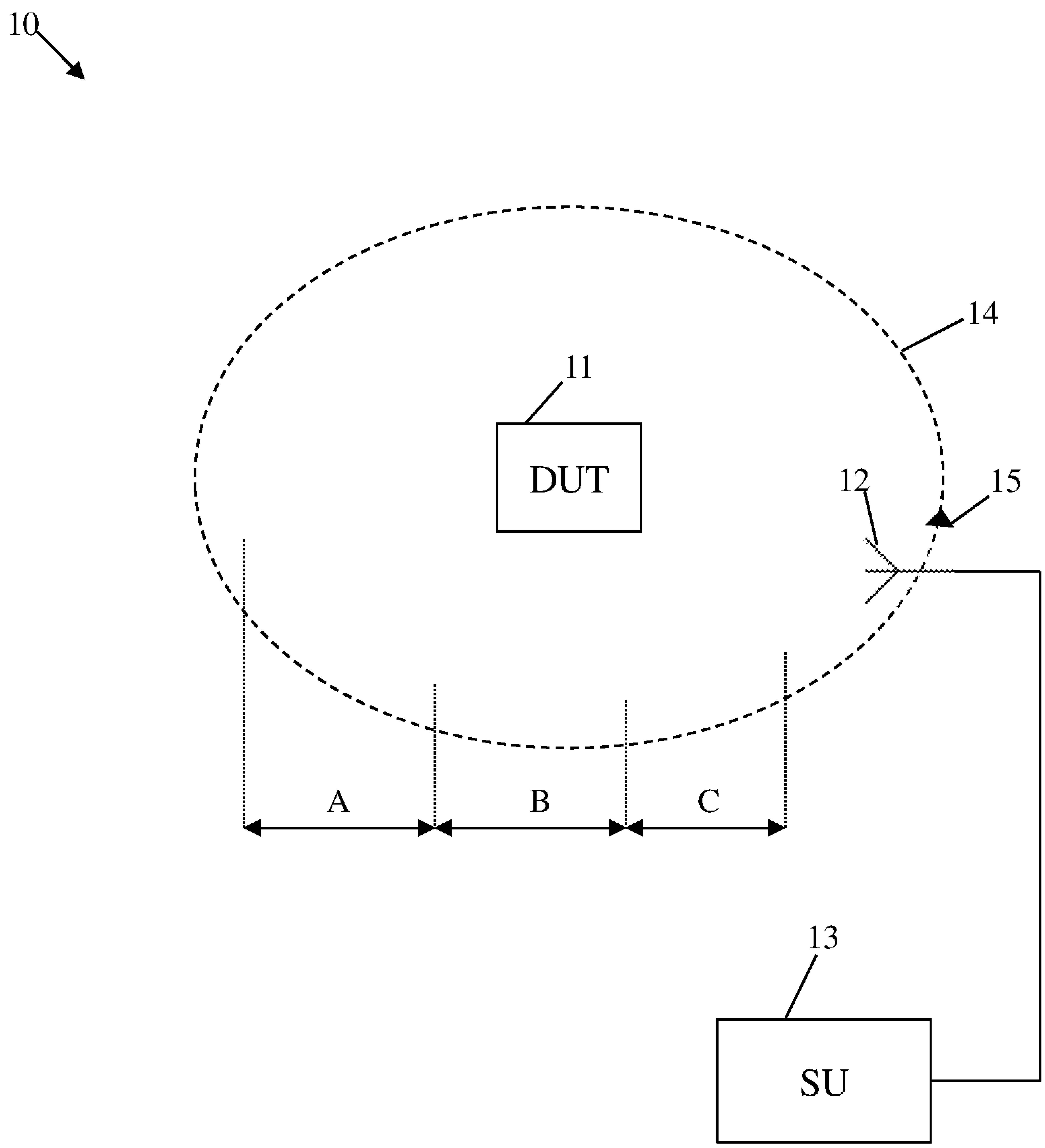


Fig. 1

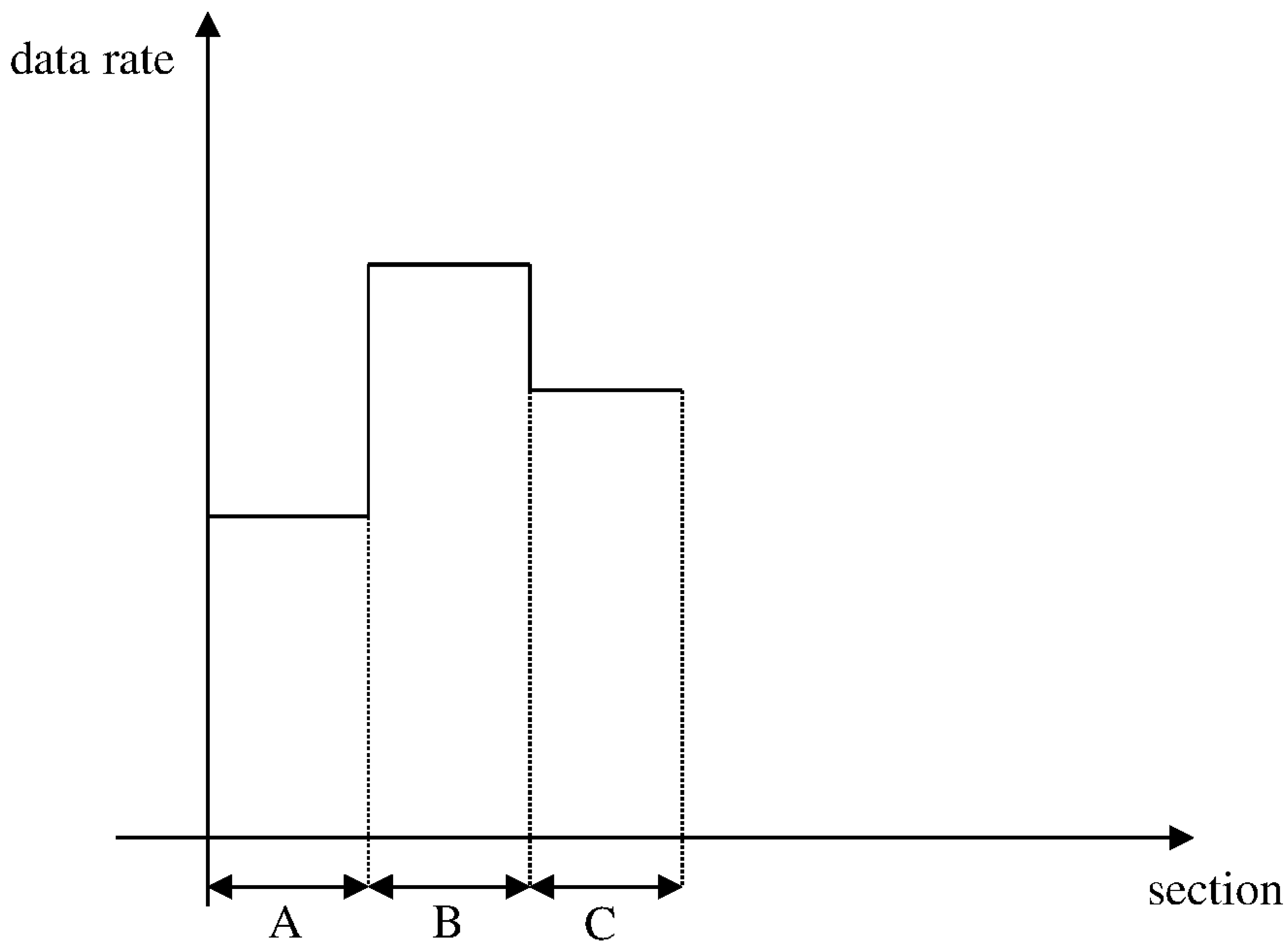


Fig. 2

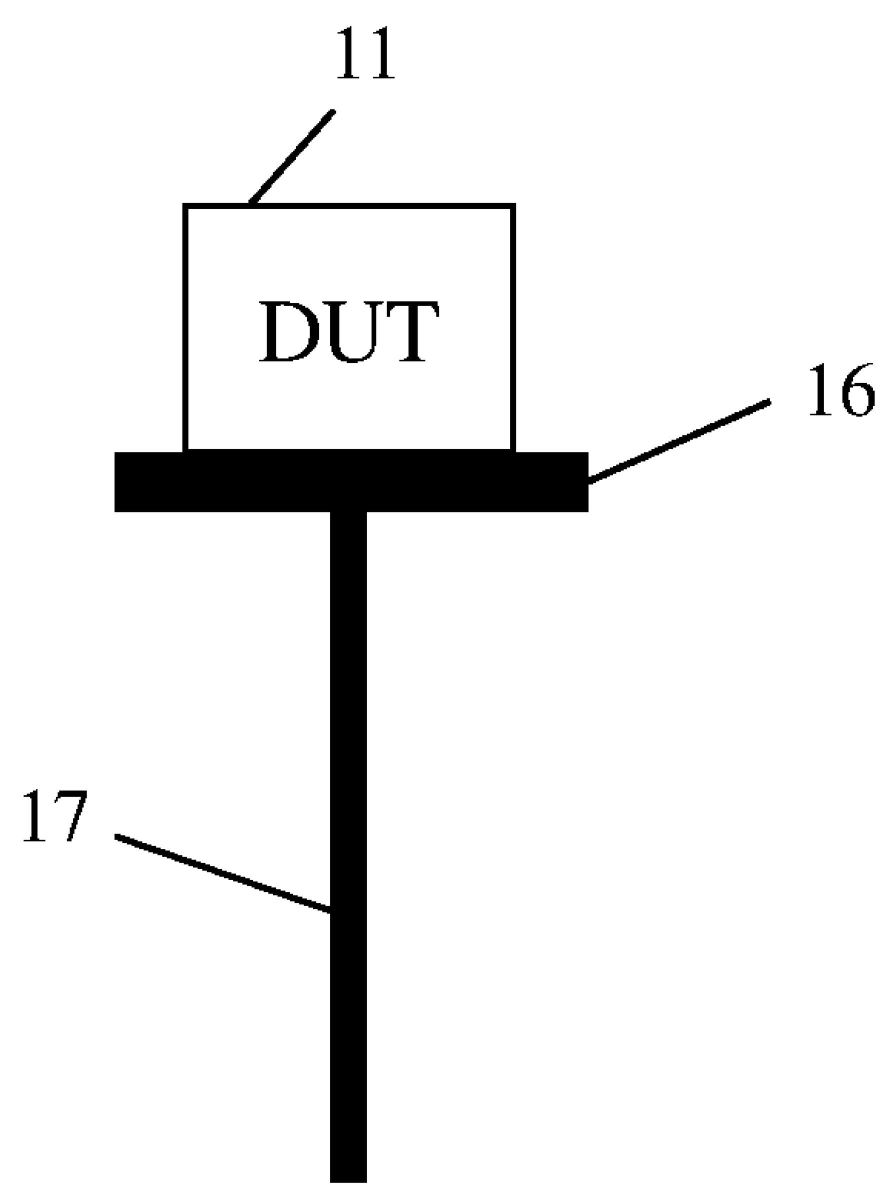


Fig. 3

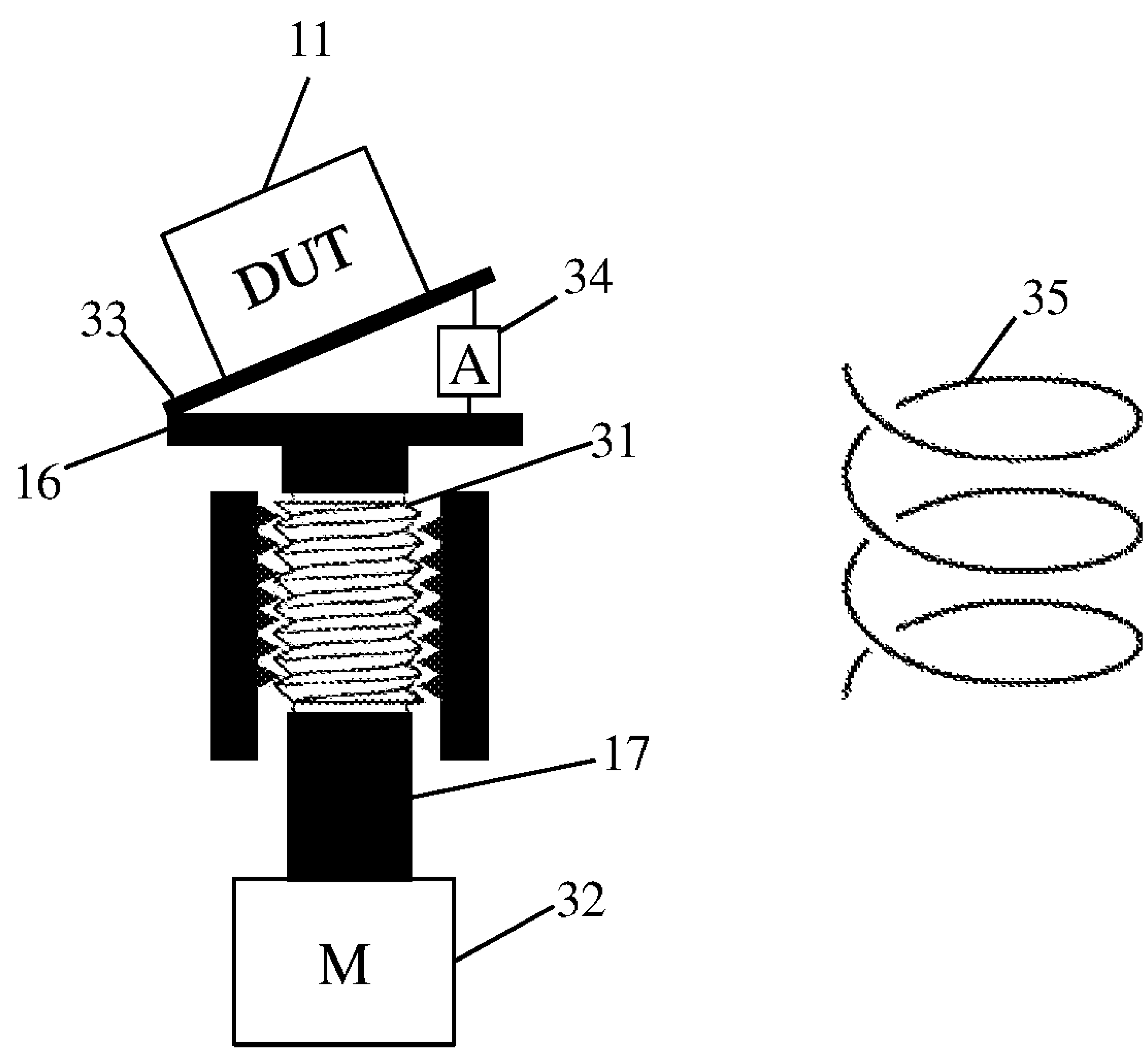


Fig. 4

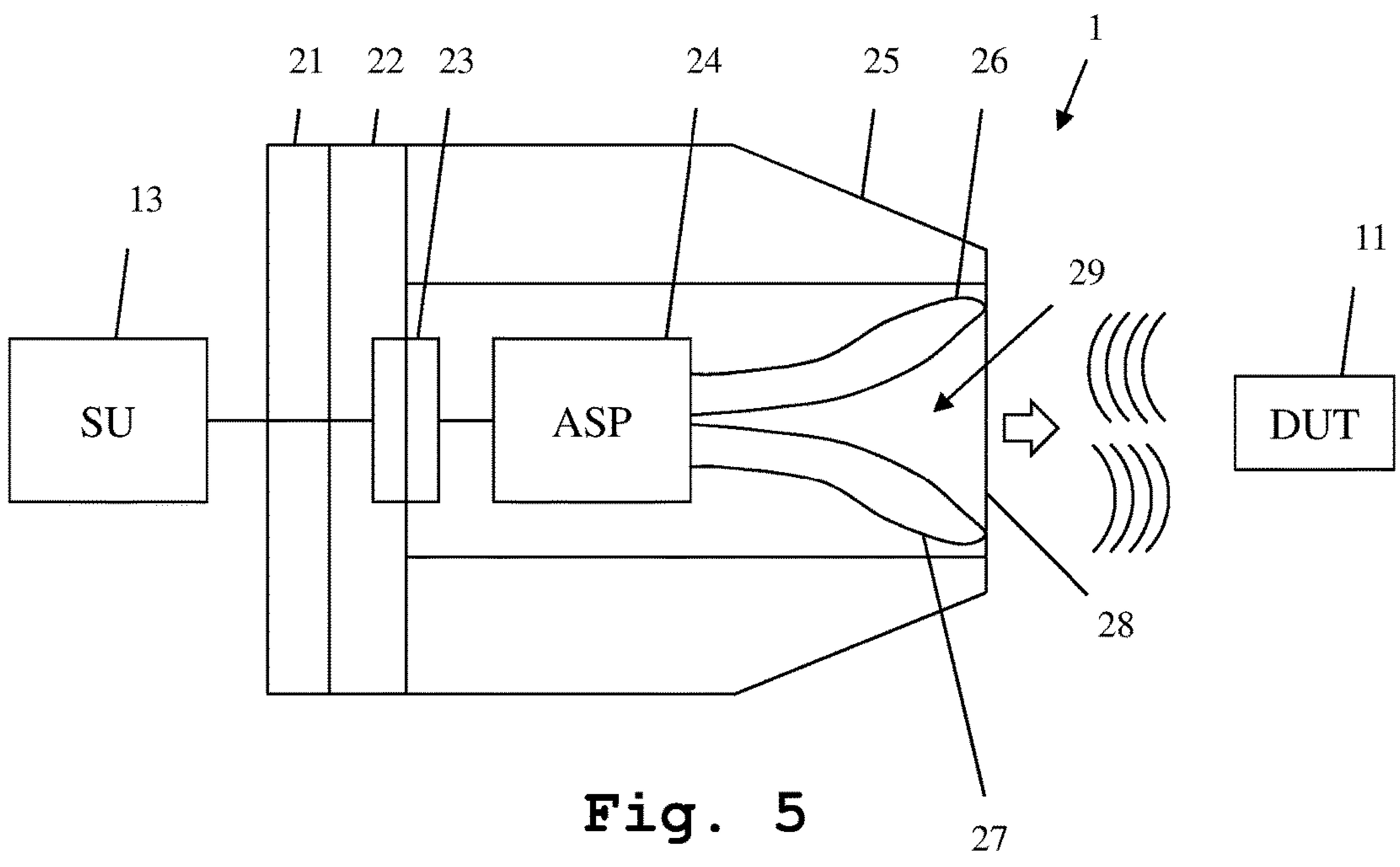


Fig. 5

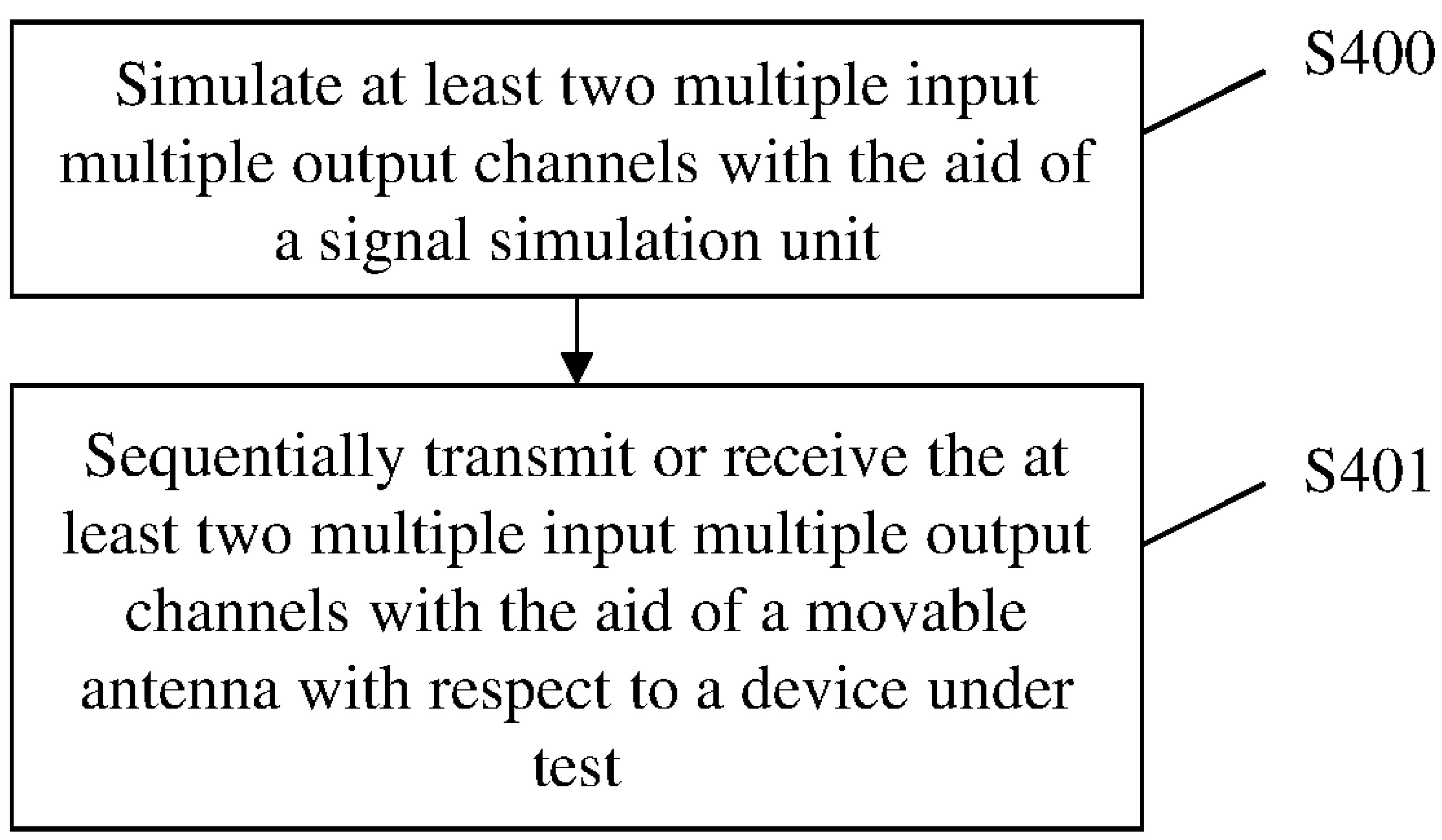

Simulate at least two multiple input multiple output channels with the aid of a signal simulation unit
S400
Sequentially transmit or receive the at least two multiple input multiple output channels with the aid of a movable antenna with respect to a device under test
S401

Fig. 6

TEST SYSTEM AND METHOD FOR TESTING MULTIPLE INPUT MULTIPLE OUTPUT CAPABILITIES

TECHNICAL FIELD

The invention relates to a test system and a method for testing multiple input multiple output capabilities especially with the aid of a single antenna being movable.

BACKGROUND ART

Generally, in times of an increasing number of wireless communication applications employing MIMO (Multiple Input Multiple Output) systems such as LTE (Long Term Evolution), there is a growing need of a testing device and a testing method for testing devices under test applying such systems.

U.S. Pat. No. 8,576,947 B2 relates to a system and a method for multiple input multiple output signal testing, and more precisely, to signal conversion circuitry and method for converting a multiple input multiple output packet data signal transmission to a plurality of complex data samples for processing by shared test equipment. Disadvantageously, in accordance with said document, a single antenna is not sufficient for testing, which makes the process of testing inefficient and costly.

Accordingly, there is a need to provide a test system and a method for testing multiple input multiple output capabilities in a most efficient manner.

SUMMARY OF THE INVENTION

According to a first aspect of the invention, a test system for testing multiple input multiple output capabilities is provided. The test system comprises a device under test, a movable antenna and a signal simulation unit. The signal simulation unit simulates at least two multiple input multiple output channels. Advantageously, a single antenna being movable is sufficient for simulating at least two multiple input multiple output channels.

According to a first preferred implementation form of the first aspect, the at least two multiple input multiple output channels are transmitted or received sequentially with the aid of the movable antenna.

According to a further preferred implementation form of the first aspect, transmitting or receiving the at least two multiple input multiple output channels is possible during movement of the movable antenna. Advantageously, a virtual antenna array is emulated with the aid of the single movable antenna.

According to a further preferred implementation form of the first aspect, the device under test is movable or rotatable or tiltable.

According to a further preferred implementation form of the first aspect, the simulation of the at least two multiple input multiple output channels with the aid of the signal simulation unit is based on sequential digitization.

According to a further preferred implementation form of the first aspect, the test system comprises at least one additional antenna being movable or not movable for transmitting or receiving. Advantageously, this allows for investigating the beamforming behaviour of the device under test.

According to a further preferred implementation form of the first aspect, the movable antenna moves in a circle around the device under test.

According to a further preferred implementation form of the first aspect, the movable antenna not completely rotates around the device under test.

According to a further preferred implementation form of the first aspect, the movable antenna moves around the device under test in the sense of a cylindrical, spherical, or spiral or helical shape or trace or a combination thereof.

According to a second aspect of the invention, a method for testing multiple input multiple output capabilities is provided. The method comprises the steps of simulating at least two multiple input multiple output channels with the aid of a signal simulation unit, and sequentially transmitting or receiving the at least two multiple input multiple output channels with the aid of a movable antenna with respect to a device under test. Advantageously, a single antenna being movable is sufficient for simulating at least two multiple input multiple output channels.

According to a first preferred implementation form of the second aspect, transmitting or receiving the at least two multiple input multiple output channels is enabled during movement of the movable antenna. Advantageously, a virtual antenna array is emulated with the aid of the single movable antenna.

According to a further preferred implementation form of the second aspect, the device under test is moved or rotated or tilted.

According to a further preferred implementation form of the second aspect, the simulation of the at least two multiple input multiple output channels with the aid of the signal simulation unit is based on sequential digitization.

According to a further preferred implementation form of the second aspect, the method involves at least one additional antenna being moved for transmitting or receiving. Advantageously, this allows for investigating the beamforming behaviour of the device under test.

According to a further preferred implementation form of the second aspect, the movable antenna is moved in a circle around the device under test.

According to a further preferred implementation form of the second aspect, the movable antenna is not completely rotated around the device under test.

According to a further preferred implementation form of the second aspect, the movable antenna is moved around the device under test in the sense of a cylindrical, spherical, or spiral shape or helix or a combination thereof.

BRIEF DESCRIPTION OF THE DRAWING

Exemplary embodiments of the invention are now further explained with respect to the drawings by way of example only, and not for limitation. In the drawings:

FIG. **1** shows a block diagram of an exemplary embodiment of the first aspect of the invention;

FIG. **2** shows an exemplary function process of data rate with respect to moving the movable antenna of the invention;

FIG. **3** shows an exemplary embodiment of a device under test mount;

FIG. **4** shows a more detailed exemplary embodiment of a device under test mount;

FIG. **5** shows an exemplary embodiment of a movable antenna; and

FIG. **6** shows a flow chart of an exemplary embodiment of the second aspect of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. **1** illustrates an exemplary embodiment of a test system **10** for testing multiple input multiple output capabilities. The invention is not limited to this embodiment and all features below are explained for the purpose of example only.

The test system **10** comprises a device under test **11**, a moveable antenna **12** and a signal simulation unit **13** connected to the movable antenna **12**.

Whereas the signal simulation unit **13** is embodied to simulate at least two multiple input multiple output channels, the at least two multiple input multiple output channels are transmitted or received sequentially the aid of the movable antenna **12**.

Furthermore, the movable antenna **12** is exemplarily moved around the device under test **11** according to the dashed line **14**, wherein the direction of movement is illustrated by arrow **15**.

As it can be seen, in this exemplary case, the movable antenna **12** moves in an ellipse around the device under test **11**. In this context, it should be mentioned that the movable antenna **12** may also move in a circle around the device under test **11**. Furthermore, the movable antenna **12** may move around the device under test **12** in the sense of a cylindrical, spherical, spiral, helical shape or trace or a combination thereof. Additionally or alternatively, the movable antenna **12** may not completely rotate around the device under test **11**.

Moreover, the simulation of the at least two multiple input multiple output channels with the aid of the signal simulation unit is based on sequential digitization. In addition to this, as it can be seen from FIG. **1**, said simulation comprises different sections, exemplarily sections A, B, and C. During movement of the movable antenna **12**, the signal simulation unit **13** advantageously switches between these multiple, exemplarily three, preferably at least two, simulation sections, wherein the simulation sections especially differ in their data rate. They might also differ in the kind of modulation, length or frames, number of used MIMO antennas etc.

This situation is illustrated with the aid of the diagram according to FIG. **2**, wherein the lowest data rate of section A is followed by the highest data rate of section B which is followed by an intermediate data rate of section C.

Again with respect to FIG. **1**, it should be mentioned that the test system **10** may comprise at least one additional antenna being movable or not movable for transmitting or receiving. In this manner, the device under test **11** can advantageously be tested with respect to its beamforming behavior.

Additionally or alternatively, the device under test **11** is movable or rotatable, which may exemplarily be achieved with the aid of a device under test mount according to FIG. **3**.

The device under test mount for mounting the device under test **11** comprises a plane **16** being rotatable around an axis **17**. Additionally or alternatively, the axis **17** may allow for height adjustment or tilting or a combination thereof.

In FIG. **4**, an embodiment of the device under test mount is shown in greater detail. In this context, the device under test mount comprises a first plane **16** attached to a first end of an axis **17**, wherein the axis **17** comprises a thread **31** for moving the plane **16** up and down with the aid of a motor **32** attached to a second end of the axis **17**. As it can be seen, rotating the axis **17** with the aid of the motor **32** serves the height adjustment of the first plane **16**, and thus also of the device under test **11**.

Furthermore, the device under test **11** is attached to a second plane **33** which is attached to the first plane **16** in a tiltable manner. For the purpose of tilting the device under test **11**, and thus for tilting the second plane **33** with respect to the first plane **16**, the device under test mount comprises an actuator **34** which tilts the second plane **33** with respect to the first plane **16**.

In addition to this, FIG. **4** illustrates an exemplary trace of movement of the device under test **11** in the case that the device under test **11** is moved down in a tilted condition, which leads to the helical trace **35**.

Moreover, with respect to FIG. **5**, an exemplary embodiment of the movable antenna **12** is shown, wherein the movable antenna **12** is embodied in the form of an over the air probe **1**. Additionally or alternatively, the above-mentioned at least one additional antenna may also be embodied in accordance with FIG. **5**.

In FIG. **5**, the over the air probe **1** comprises a housing **25** which contains a substrate **28**, advantageously a printed circuit board. On the substrate **28**, two antenna elements **26**, **27** forming a tapered slot line antenna **29**, are arranged. The antenna **29** is connected to an analog signal processor **24** which is also arranged on the substrate **28**. The analog signal processor moreover is connected to a connector **23** which serves as an interface **23**. Connectable to the interface **23** is the signal simulation unit **13**, which is not part of the over the air probe **1**. The antenna **29** has a main radiation direction towards the right edge of the substrate **28**, indicated by an arrow. The device under test **11** is suitably arranged in this direction.

In order to minimize reflections from the over the air probe **1**, the housing **25** is tapered towards the main radiation direction of the antenna **29**. This tapering reduces the effective surface area, which can produce reflections. In order to further reduce such reflections, the housing **25** can be fabricated from an electromagnetic radiation absorbing material. It can also be covered with such a material or can be coated with an absorptive paint. The housing **25** furthermore comprises a back plate **21**, which is covered with absorptive material **22** in order to further reduce reflections.

The over the air probe **1** is suitable for two types of measurements. In a first type of measurement, a first measuring signal emitted from the device under test **11** is received by the antenna **29** and handed to the analog signal processor **24**. The analog signal processor **24** reduces the frequency of the first measuring signal resulting in a frequency reduced first measuring signal. This is for example done by down-converting the first measuring signal using a mixer. Additionally, the analog signal processor in this case can comprise one or more filters for filtering the first measuring signal or the frequency reduced first measuring signal, a power sensor, which can be used for directly measuring a power of the frequency reduced first measuring signal, an amplifier for amplifying the first measuring signal or the first frequency reduced measuring signal, and a radio frequency switch for switching between different measuring options.

The processed frequency reduced measuring signal is then handed on to the connector **23**, which passes on the signal to for example the external signal simulation unit **13** for further processing the frequency reduced measuring signal.

Alternatively, the over the air probe **1** can be used for another type of measurement. In this case, the connector **23** receives a frequency reduced second measuring signal from the signal simulation unit **13**. It is handed on to the analog signal processor **24**. The analog signal processor **24** increases the frequency of the frequency reduced second measuring signal resulting in a second measuring signal. This is for example done by mixing the frequency reduced second measuring signal with a further local oscillator signal. The second measuring signal is then transmitted by the antenna **29** to the device under test **11**. Also, in this case, the analog signal processor can comprise additional components. The analog signal processor can comprise a filter, for filtering the second measuring signal and/or the second frequency reduced measuring signal. Also, the analog signal processor can comprise an amplifier for amplifying the second measuring signal and/or the second frequency reduced measuring signal. Moreover, the analog signal processor can comprise a radio frequency switch, adapted to switch between different operating modes of the over the air probe **1**.

Finally, FIG. **6** shows a flow chart of an exemplary embodiment of the inventive method. In a first step **S400**, at least two multiple input multiple output channels are simulated with the aid of a signal simulation unit. Then, in a second step **S401**, the at least two multiple input multiple output channels are sequentially transmitted or received with the aid of a movable antenna with respect to a device under test.

While various embodiments of the present invention have been described above, it should be understood that they have been presented by way of example only, and not limitation. Numerous changes to the disclosed embodiments can be made in accordance with the disclosure herein without departing from the spirit or scope of the invention. Thus, the breadth and scope of the present invention should not be limited by any of the above described embodiments. Rather, the scope of the invention should be defined in accordance with the following claims and their equivalents.

Although the invention has been illustrated and described with respect to one or more implementations, equivalent alterations and modifications will occur to others skilled in the art upon the reading and understanding of this specification and the annexed drawings. In addition, while a particular feature of the invention may have been disclosed with respect to only one of several implementations, such feature may be combined with one or more other features of the other implementations as may be desired and advantageous for any given or particular application.

What is claimed is:

1. A test system for testing multiple input multiple output capabilities, the system comprising:

a device under test,

a movable antenna moves around the device under test, and

a signal simulation unit,

wherein the signal simulation unit simulates at least two multiple input multiple output channels,

wherein the simulation comprises different sections,

wherein the sections differ in the kind of modulation, length or frames,

wherein a device under test mount comprises a first plane that is rotatable around an axis, wherein the axis comprises a thread for a vertical movement of the first plane, and

wherein a second plane is attached to the first plane in a tiltable manner.

2. The test system according to claim **1**,

wherein the at least two multiple input multiple output channels are transmitted or received sequentially with the aid of the movable antenna.

3. The test system according to claim **2**,

wherein transmitting or receiving the at least two multiple input multiple output channels is possible during movement of the movable antenna.

4. The test system according to claim **1**,

wherein the device under test is movable or rotatable or tiltable.

5. The test system according to claim **1**,

wherein the simulation of the at least two multiple input multiple output channels with the aid of the signal simulation unit is based on sequential digitization.

6. The test system according to claim **2**,

wherein the test system comprises at least one additional antenna for transmitting or receiving.

7. The test system according to claim **6**,

wherein the additional antenna is movable or rotatable or tiltable.

8. The test system according to claim **1**,

wherein the movable antenna moves in a circle around the device under test.

9. The test system according to claim **1**,

wherein the movable antenna not completely rotates around the device under test.

10. The test system according to claim **1**,

wherein the movable antenna moves around the device under test in a cylindrical or spherical or spiral or helical trace or a combination thereof.

11. A method for testing multiple input multiple output capabilities, the method comprising the steps of:

simulating at least two multiple input multiple output channels with the aid of a signal simulation unit, and

sequentially transmitting or receiving the at least two multiple input multiple output channels with the aid of a movable antenna with respect to a device under test,

wherein the movable antenna moves around the device under test,

wherein the simulation comprises different sections,

wherein the sections differ in the kind of modulation, length or frames,

wherein a device under test mount comprises a first plane that is rotatable around an axis, wherein the axis comprises a thread for a vertical movement of the first plane, and

wherein a second plane is attached to the first plane in a tiltable manner.

12. The method according to claim **11**,

wherein transmitting or receiving the at least two multiple input multiple output channels is enabled during movement of the movable antenna.

13. The method according to claim **11**,

wherein the device under test is moved or rotated or tilted.

14. The method according to claim **11**,

wherein the simulation of the at least two multiple input multiple output channels with the aid of the signal simulation unit is based on sequential digitization.

15. The method according to claim **11**,

wherein the method involves at least one additional antenna being moved for transmitting or receiving.

16. The method according to claim **11**,

wherein the movable antenna is moved in a circle around the device under test.

17. The method according to claim **11**,

wherein the movable antenna is not completely rotated around the device under test.

18. The method according to claim **11**,

wherein the movable antenna is moved around the device under test in a cylindrical, spherical, or spiral or helical trace or a combination thereof.

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